OPTIMIZATION OF MULTIHOP RELAYING IN WIMAX (IEEE 802.16)

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Abstract: In IEEE 802.16j standard, Relay Stations (RS) play a promising role of extending the range of a Base Station (BS). This architecture is suitable to areas with limited infrastructure, such as rural areas, since it is difficult to install many BSs, with each having a wired connection. In this paper, we present an optimization model that finds the number of RSs and their locations to serve a customer base. We also show how our model can be adapted to make the planning in real-life scenarios where there are obstacles, such as mountains and lakes, in the planning area. We focus on three of these issues- relay placement for coverage extension, capacity improvement with relays and relay automatic repeat request (ARQ) protocols.

Keywords: WiMax, IEEE 802.16j, Relay, cooperative diversity schemes, relay optimization, relaying scheme, Relay Station, capacity, OFDM, MOMO, coverage extension.

I. INTRODUCTION

Broadband wireless access networks have gathered a great momentum recently in terms of industry support, research and pilot network deployment. The groups of companies that support the development of the IEEE 802.16 family of standards, commercially known as the WiMAX, are members of the WiMAX Forum. The forum oversees the promotion of WiMAX through activities such as negotiating bandwidth licensing policies and authoring requirements of interoperability tests between equipment from various vendors. Research in wireless broadband networks has also picked up actively in many fields including resource allocation, relays placement, handover between cells, quality of service and others. Also, there are tens or even hundreds of pilot networks deployed around the globe to test drive the WiMAX technology. This is the 802.16x wireless metropolitan area network (WMAN) specification, which is being developed and promoted by the WiMAX industry group, whose most powerful members are Intel and Nokia. As with Wi- supporters are focusing in particular on broadband last mile in unwired areas, and on backhaul for hotspots. These vendors are finally giving broadband wireless the teeth it needs, with a standards base, to take on wired options for the last mile and for long distance networking. The WiMAX (Worldwide Interoperability for Microwave Access) group was actually set up two years ago by Nokia, Ensemble and the OFDM Forum, but gained a new lease of life in April when it was revived by Nokia in collaboration with Intel and added five new members, with nine more joining in May. The non-profit group takes a similar role to the Wi-Fi Alliance in WLANs, backing development of wireless Man products based on 802.16 and working on standards certification and interoperability testing. The initial version of the standard operates in the 10-66GHz frequency band and requires line of sight towers, but the 802.16a extension, ratified in March, uses the lower frequency of 2-11GHz, easing regulatory issues, and does not require line of sight. It boasts a 31 mile range compared to Wi-Fi's 200-300 yards, and 70Mbps data transfer rates. WiMAX president Margaret Labrecque says that collaborating on mass market products will achieve similar economies of scale to those seen in Wi-Fi WLAN devices. She says base stations will cost under $20,000 and support 60 enterprise customers with T1-class connections. Systems based on the mobile version of the standard, which should ship towards the end of next year, about six months after fixed wireless products, will be able to achieve long distance wireless networking and will have far greater potential than Wi-Fi hotspots to provide ubiquitous coverage to rival that of the cellular network.

II. LITERATURE SURVEY

After reading several IEEE paper we have concluded that planning of relay station increases the capacity and range of WiMAX. To maximize the capacity of the network to transport the highest amount of data subject to meeting the demands of user's traffic, while minimizing the required infrastructure and covering the requested area of service. We consider that the majority of the traffic originates from, or is destined to the BS; so traffic will be between the BS and the subscriber stations (SS) or mobile stations (MS). Also, there is traffic in the uplink and downlink directions and we consider that more traffic will go from the BS, across the relays, to the SSs or MSs; that is, the downlink traffic exceeds the uplink traffic. Relays are introduced in cellular networks to achieve improvement in the following aspects:

(i). Coverage: RSs improve the network coverage to MSs, especially at the cell edge A cell edge MS may experience poor received SNR from the BS, but being closer to the RS, the MS receives a strong signal from the RS with high probability. Thus, introduction of RSs increases the total coverage area of the cell. By increasing the cell radius the number of base stations would decrease. If the total cost of RSs is less than that of this decrease in the base stations, the infrastructure cost would reduce to a great extent.

(ii) Capacity: Alternative to increasing the coverage area, RSs can be used to increase the capacity of the cell. Because of the improvement in signal quality experienced by users at the cell edge, these users require lesser resources from the BS. For example, in cellular OFDMA systems, the number of subcarriers required by the user is smaller when the MS is served via an RS. Thus, the same resources can be shared among a larger number of users resulting in overall capacity improvement.

(iii) Optimal Relay placement for Coverage Extension: The deployment of RS in cellular networks helps improve the system capacity and coverage area. In a relay-assisted cellular system, mobile stations (MSs) have the diversity benefit of two possible links, the direct link to the BS, and a link via RS. Thus, incoming calls experience lower blocking probability and the call can support a higher traffic load of users. The introduction of RSs also helps increase coverage radius of the cell by providing high SNR to the cell edge MSs. Thus, the infrastructure cost of deploying more base stations is reduced. In this work, we concentrate on the role of RSs in cellular coverage extension. The increase in coverage radius of the cell depends upon the placement of RSs in the cell. This is because the location of RSs affects the quality of the BS-RS and RS-MS links as well as the inter-cell interference from neighboring cells. If an RS is placed too close to the cell edge, packets will experience a low SNR on the BS-RS link. Also, an RS close to the cell edge will cause higher interference to the neighboring cells. On the other hand, if the RS is placed close to the base station, the RS-MS link quality will suffer and cell edge users shall not benefit from the introduction of RSs. Thus for a given set of system parameters, there is a need for optimal RS placement to achieve maximum extension of the coverage radius of the cell. Only a few researchers so far have addressed the issue of optimal placement of cellular RSs.

(iv) Capacity Improvement with Relays: Recent years have witnessed the emergence of Orthogonal Frequency Division Multiple Access (OFDMA) as one of the dominant Medium Access Control (MAC) techniques for next-generation wireless networks .OFDMA employs multicarrier modulation to combat frequency selective fading. Each base station (BS) has a set of orthogonal subcarriers, subsets of which are allocated to users in the cell. Due to limited availability of spectrum, a frequency reuse factor is most common in multi-cell OFDMA architecture. In reuse, by allocating a random permutation of subcarriers to users in each cell, the intercell interference may be averaged out and hence may not affect the system performance severely. Erlang capacity corresponds to the traffic load that a cell can support while providing acceptable service to the users. It is an important parameter from the capacity planning perspective and is used as a performance metric for admission control algorithms. We determine the downlink Erlang capacity of cellular OFDMA. The main idea is to take into account the fact that each incoming user requires a random number of subcarriers depending upon its position in the cell, fading and inter-cell interference. Erlang capacity is a well studied topic for the traditional Global System for Mobile communications (GSM) cellular systems . The capacity of these systems for a given blocking probability is determined by the Erlang-B formula. Erlang capacity has also been studied extensively in the context of Code Division Multiple Access (CDMA) system. Unlike GSM in which a user is blocked if all the time or frequency channels at the BS are occupied, in CDMA, an incoming user is blocked if it increases the interference and causes outage conditions for the existing users. Though OFDMA is also a form of Frequency Division Multiple Access (FDMA), the fundamental difference between Erlang capacity of FDMA systems and cellular OFDMA is that in the latter, each call requires a random number of subcarriers. The idea of incoming users requiring random number of resources has been addressed in operations research literature. A queuing system with Poisson arrivals of customers and exponentially distributed service times has been analyzed and the probability distribution of the waiting times of customers has been determined in . Only a few studies focus on determining the Erlang capacity of cellular OFDMA In , Erlang capacity is used as a performance metric for comparison of various adaptive resource allocation algorithms. In, the uplink capacity of relay-assisted cellular networks is analyzed. Erlang capacity analysis of traditional cellular systems like Global System for Mobile communications (GSM) cannot be applied to cellular OFDMA because in the latter, each incoming call requires a random number of subcarriers.

III. CONCEPY OF RELAY STATIONS (RS)

The concept of relay originated as an information theoretical scenario in paper-Capacity theorems for the relay channel‖ by T Cover and AE Gamal in 1979. In this paper they considered a relay channel along with the main channel where a relay acts as a helper node in the transmission of information bits. An upper bound on the capacity of this channel was found. Also the capacity was found in the case of degraded relay channel.

The utility of such a helper node was not realized in practice until recently when some practical issues had solution based on this relay concept. Let us look at some of these issues typical to WiMAX.

(i) Coverage limitation due to low Signal to Noise Ratio (SNR) at the cell edges. This is due to the significant signal attenuation caused when operating at high spectrum

(ii) Poor signal reception due to coverage holes.

(iii) Higher cost of increasing the number of base stations

(iv) High power requirement at mobile stations due to communicating at large distances at high speeds.

The definition of a relay as provided in IEEE 802.16j is as follows: ―A generalized equipment set, dependent on a multihop relay base station (MR-BS) providing connectivity, to other RSs or subscriber stations (SS). A relay can be of as a miniature base station that enjoys line of sight connectivity with another relay or a base station. Unlike a base station a relay is not connected to the wired backhaul.

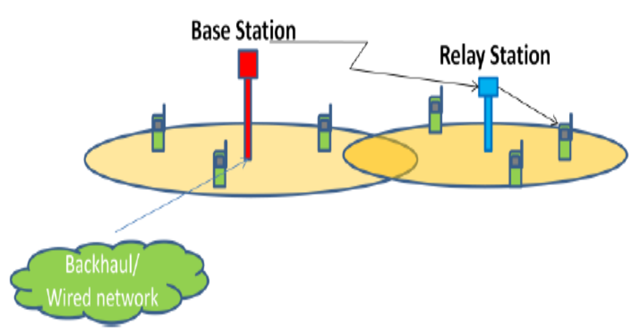

Fig.1 Concept of Relay.

Most of the existing broadband wireless systems rely on Line Of Sight (LOS) communications. WiMAX has been targeted to provide speeds upto 30Mbps at large distances. Hence coverage as well as throughput goals of WiMAX are very ambitious. Current cellular systems designed mainly for voice traffic can work without LOS constraint. Hence WiMAX needs to increase the density of base stations to provide LOS communication to all mobile stations. This incurs a large infrastructural cost in deployment of WiMAX. A relay is an alternative to this solution, since relays are expected to operate at lower powers and without connection to any wired backhaul. Also the proximity of relays to the mobile stations (MS) means that less power expenditure at the MSs. As a relay cannot transmit and receive at the same time due to large difference between the transmit and receive powers at the antennas, the end to end transmission between the base station (BS) and the mobile station (MS) and in the reverse direction occurs in two phases per page.

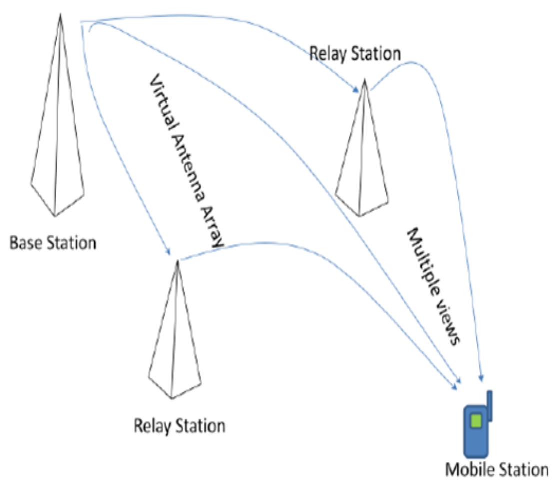

Fig. 2 Cooperative Diversity schemes.

Cooperative diversity schemes can be classified into following types:

1. Cooperative MIMO Diversity: The MS and the RS listen to the transmission of BS in the first phase. In the second phase BS and RS simultaneously transmit to MS. During the second phase BS and RS make use of STBC. The MS used maximal ratio combining (MRC) to combine the multiple copies of data. This scheme is the combination of both transmits and receives diversity, hence called MIMO diversity. BS and the RS should use the same AMC scheme during the second phase.

2. Cooperative Transmit Diversity: The MS does not listen to the transmission of BS during the first phase. During the second phase BS and RS simultaneously transmit to MS using STBC. The advantage of this scheme is that AMC scheme can be different between two phases. Hence good channel conditions between the RS and MS can be exploited.

3. Cooperative Receive Diversity: The MS and RS receive data from the BS during the first phase and during the second phase only the RS transmits to the MS with the same AMC scheme. This scheme can never outperform Cooperative MIMO diversity.

4. Cooperative Selection Diversity: BS dynamically chooses between conventional relaying and direct transmission. Conventional relaying means that the RS receives data from the BS in first phase and during the second phase MS simply listens to RS.

5. Adaptive Cooperative Diversity: The best method is to choose from the above mentioned schemes, based on the cooperative diversity gain, delay, availability of resources, and complexity.

IV. COMPARATIVE STUDY OF COOPERATIVE RELAYING SCHEMES

Cooperative relaying schemes can be classified into different categories:

1. Transmit diversity
2. Receive Diversity
3. Amplify and forward
4. Decode and forward

In this experiment, we try to model these schemes and compare their performance with increase in BS to MS distance.

SYSTEM MODEL:

One cell with a single base station

Four equally spaced RS at a distance of 10km from the BS

BS transmit power = 27.3 dB

RS transmit power= 20.3 dB

BS to RS distance = 10km

Power of additive noise = -130 dB

Path loss exponent = 3.5

Then the SNR at the mobile station is given by:

SNR (dB)= Pt(dB)-Pn(dB)-35log(r)

Where r is its distance of MS from BS

Adaptive modulation and coding (AMC) is employed which means that the transmitter chooses a suitable modulation scheme and coding rate based upon the instantaneous value of SNR.

1. **No Relay:** This is a direct BS to MS communication assuming that no relay exists in the cell. As expected the throughput decreases as we move away from the base station.

2. **Simple relaying without cooperative diversity:** In this scenario the BS transmits to the RS in the first phase. While in the second phase the RS transmits to the MS. The two phases may not be of equal duration. It is assumed that the RS is placed in such a way that it can use the maximum rate of 64-QAM 5/6 AMC. Hence the SNR from the RS to MS decides the AMC.

3. **Transmit diversity Amplify and Forward:** In this scheme, the transmission occurs in two phases: In the first phase BS transmits to the RS. And in the second phase, both RS and BS transmit simultaneously to the MS. In Amplify and forward relaying, the symbols are not decoded at the relay. Hence error correction is not performed by the relay. For AF relaying, the two time phases must be of equal length and same AMC mode should be used in both the phases.

4. **Transmit diversity Decode and Forward:** This scheme is similar to the previous scheme. However in this case the relay performs error correction on the data received in first phase. In the second phase both the RS and BS transmit simultaneously using a suitable AMC mode that can be different from the one used in the first phase. Hence, the two phases durations may be different.

5. **Receive diversity Amplify and Forward:** In this scheme both the MS and RS listen to the BS transmission during the first phase and in the second phase only the RS transmits to the MS. The MS then uses MRC on the signals received in both the phases.

6. **Receive diversity Decode and Forward:** This scheme is similar to the one described previously. The only difference is that the intermediate RS decodes the signal, performs error correction and then transmits to the MS in the second phase. Both the phases should be of equal duration.

Table 1 Throughput formulae for different relaying schemes

Sr No	Relaying Scheme	Effective throughput	Comments
1	No relay	$thr(\gamma_{BM})$	Direct BS to MS communication
2	Simple relaying	$\frac{thr(\gamma_{BR})thr(\gamma_{RM})}{R(\gamma_{BR})+R(\gamma_{RM})}$	DF relay is assumed here.
3	Tx Diversity AF	$0.5Thr\left(\frac{\gamma_{BM}+\frac{\gamma_{BR}*\gamma_{RM}}{1+\gamma_{BR}}}{1+\frac{\gamma_{RM}}{1+\gamma_{BR}}}\right)$	Two phases must be of equal duration.
4	Tx Diversity DF	$\frac{thr(\gamma_{BR})thr(\gamma_{hat})}{R(\gamma_{BR})+R(\gamma_{hat})}$ where $\gamma_{hat}=\gamma_{BM}+\gamma_{BM}$	Two phases can be of different duration.
5	Rx Diversity AF	$0.5thr\left(\frac{\left(\gamma_{BM}+\frac{\gamma_{BR}*\gamma_{RM}}{1+\gamma_{BR}}\right)^2}{\gamma_{BM}+\frac{\gamma_{BR}*\gamma_{RM}}{1+\gamma_{BR}}+\frac{\gamma_{RM}^2\gamma_{BR}}{(1+\gamma_{BR})^2}}\right)$	Two phases must be of equal duration.
6	Rx Diversity DF	$0.5thr(\gamma_{BM}+\gamma_{BM})$	Two phases must be of equal duration.

V. SIMULATION RESULTS

1. No Relay

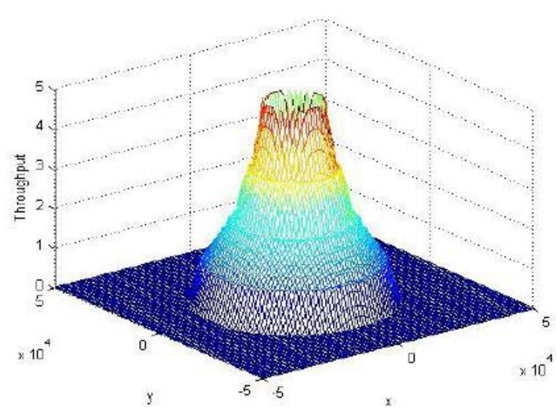

Fig. 3 No relay.

2. Simple Relay

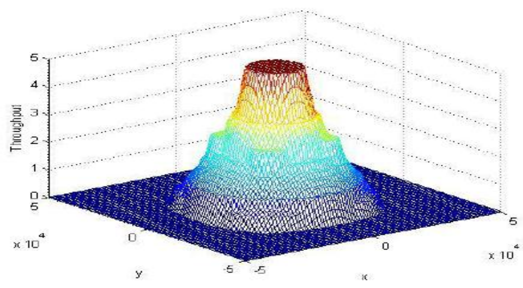

Fig. 4 Simple Relay.

3. Cooperative Diversity (Decode And Forward Relay)

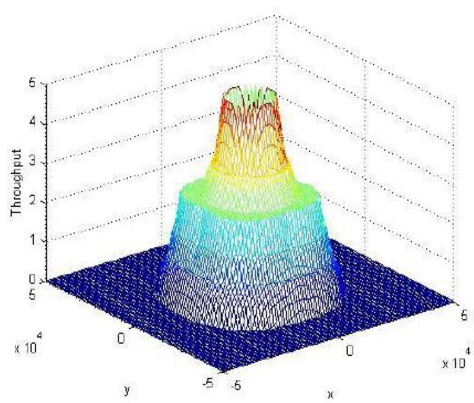

Fig. 5 Decode and Forward Relay (Cooperative Diversity)

4. Comparison of different cooperative diversity schemes

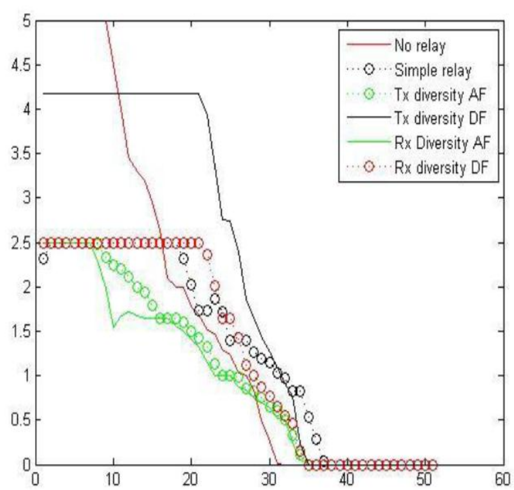

Fig. 6 Comparison of various relaying techniques.

5. Observations

DF schemes provide better performance than the AF schemes. However DF schemes are more computationally intensive at the RS. Also transmit diversity seems to perform better than receive diversity. However receive diversity does not need the BS to transmit during the second phase. Hence it can schedule another user in this slot. The benefit of receive diversity will be visible when we do network simulations.

VI. CONCLUSION

In this chapter, we have determined the capacity of a WiMAX OFDMA system with 1:1 frequency reuse. The key idea of the approach is to divide incoming calls into classes according to their subcarrier requirement. Arrival rates of these classes ha been obtained from the probability distribution of the number of subcarriers required by users. We then extend this analysis to a relay- assisted WiMAX system, obtain numerical results for the optimal RS location and BS-RS subcarrier distribution to achieve maximum capacity. In above simulation we concluded that when we use simple relay station then our throughput is increased in WiMAX network and our end user had a good strength of SNR and also good throughput. But when we use cooperative relaying then our SNR is high to our end user and signal strength is also high .That why we use cooperative relaying in WiMAX.

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